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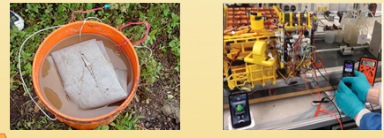


Introduction to Microbial Fuel Cells

Jackie Guilford



What Are Microbial Fuel Cells?

- Microscopic organisms are all around us
 - ~10 million trillion microbes per human on earth
- These microbes create vast amounts of energy as they decompose organic matter
- Microbial fuel cells (MFCs) harvest that energy to generate usable electricity




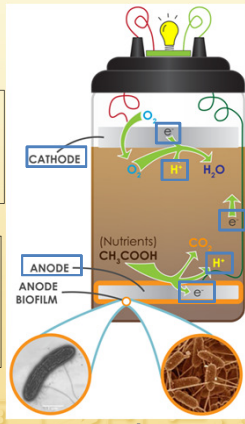
How Do MFCs Work?

- Cellular respiration** is the process by which organisms convert food into usable energy
- Our bodies usually respire **aerobically**
 - released electrons combine with **oxygen** to form water
- Some microbes in MFCs respire **anaerobically**
 - occurs in the **absence of oxygen**
 - in anaerobic respiration in MFCs, released electrons are captured... and used to power electrical devices






The MudWatt

- The MudWatt is an MFC designed to be used in the classroom
- MudWatt Components**
 - Cathode** (+ electrode) - rests on top of the soil
 - Anode** (- electrode) - buried at a certain depth within the soil
 - Wires** - connect the anode and cathode to our board
 - Soil** - from your school grounds
 - a teaspoon of soil contains a diverse community of up to 1 billion bacteria
 - a small percentage of these bacteria are **exoelectrogenic**... expel electrons to electron acceptors in the environment, such as iron... or the MudWatt anode








- The **anode** is populated with a biofilm of **anaerobic bacteria** that generate CO₂, electrons, and protons as they digest organic matter in the soil
- The **cathode** is populated with **aerobic bacteria** that combine **oxygen** with electrons and protons to form water
- The **protons** are transferred to the cathode compartment through the soil (distance is important)
- The **electrons** move from the anode to the cathode through an external electric circuit; electricity can be harvested by placing a load in the circuit

How Microbial Fuel Cells Can Save the World

- Problem #1: Global Warming**
 - MFCs produce clean energy *without burning fossil fuels*
- Problem #2: Lack of freshwater**
 - MFCs can decontaminate our wastewater *and desalinate ocean water while producing energy*
- Problem #3: Polluted soil**
 - MFCs can decontaminate soils *at the same time as generating clean water and energy*


REVIEW Published in Science in August 2012

Uses for MFCs

Conversion of Wastes into Bioelectricity and Chemicals by Using Microbial Electrochemical Technologies



Bruce E. Logan^{1*} and Korneel Rabey²


- MFCs can be used to create renewable energy in the process of decomposing waste products
- Wastewater**
 - Treatment of organic-rich wastewater currently consumes ~3% of electrical power produced in the US
 - The potential energy contained in our nation's wastewater contains enough energy to generate more than 3% of electric power consumed in the US
- Agriculture**
 - Agricultural waste contains enough biomass to generate more than 100% of the power that is consumed in the US

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Uses of MFCs in Developing Countries

- A team of Harvard students used dead leaves and compost to power a small LED lamp for up to a year in Namibia
- The Lebôné company in Cambridge, MA put graphite cloth (anode) in the bottom of a bucket along with chicken wire (cathode) and a mud/manure/sand/salt water mixture
 - The device charged a battery that powered an LED for 4-5 five hours per evening
- A group of Berkeley students designed an MFC made of a plastic water bottle, aluminum can ends (anode and cathode), copper wire, fish compost, and an LED bulb for use in rural Panama

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COMMUNICATION View Article Online

Waste to real energy: the first MFC powered mobile phone


Cite this: *Phys. Chem. Chem. Phys.*, 2013, 15, 15172
 Received 18th June 2013, Accepted 15th July 2013
 DOI: 10.1039/c3cp23888h
 www.rsc.org/pccp

This communication reports for the first time the charging of a commercially available mobile phone, using Microbial Fuel Cells (MFC) production of hydrogen from urine.¹ Struvite, which consists of magnesium, ammonium, and phosphate, and precipitates

UK Scientists Create World's First Pee-Powered Cell Phone
 by Lori Zimmer, 07/17/13
Read under: News, Renewable Energy



In the 24 hours it took to fully charge the phone, 2 outgoing calls were made, 2 text messages were received and 1 was sent

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Breweries

- Brewing beer is an energy intensive and water intensive process
 - it can take 10 L of water to produce 1 L of beer
 - the wastewater needs to be treated before it can be discharged to sewage
- Bear Republic Brewery in Cloverdale will be the first brewery to install MFCs to clean wastewater while concurrently generating electricity
 - generate clean water and energy on-site, significantly reduce the brewery's carbon footprint, save money

EcoVolt
 The World's First Bioelectric Treatment Process

EcoVolt is a breakthrough wastewater treatment system that leverages electricity active microbes to create clean water and high quality renewable methane gas from wastewater.

EcoVolt helps industrial beverage producers, particularly breweries, wineries, as well as food processing plants, generate energy from their wastewater streams, decreasing their carbon footprint & turning environmental liabilities into sources of revenue.




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Wineries

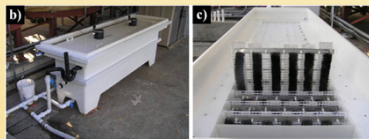
Appl Microbiol Biotechnol (2011) 89:2053–2063
 DOI 10.1007/s00253-011-3130-9


BIOENERGY AND BIOFUELS

Performance of a pilot-scale continuous flow microbial electrolysis cell fed winery wastewater

Roland D. Cusick · Bill Bryan · Denny S. Parker · Matthew D. Merrill · Maha Mchanna · Patrick D. Kiey · Guangli Liu · Bruce E. Logan


- Napa Wine Company was the site of a 1,000L continuous flow microbial electrolysis cell, which contained 144 electrode pairs in 24 modules
- Dr. Michael Cohen at Sonoma State University is collaborating with local breweries and wineries to purify their wastewater on-site



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Bioremediation

- Research ongoing to build MFCs that can generate power while breaking down contaminants including benzene, uranium, and petroleum hydrocarbons

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Microbial Fuel Cell Cleans Wastewater, Desalinates Seawater, and Generates Power
NOT BAD FOR A MICROBE
By Day O'Leary Posted August 6, 2009

Desalination

- Desalination is an extremely energy intensive process
- Microbial desalination cells contain a compartment between the anode and cathode where salt water passes
- As wastewater is cleaned by the MFC, the Na^+ is sequestered at the anode and the Cl^- is sequestered at the cathode, leaving behind salt-free water
- Microbial desalination cells treat wastewater, create drinking water, and generate electricity



"scoring a trifecta of sustainable tech in one neat little package"




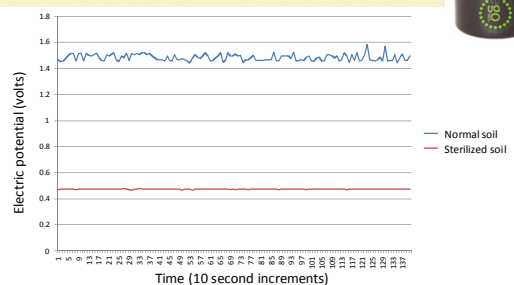


Wireless Sensor Networks



- MFCs can power electronics that require low voltage such as wireless sensors put in inaccessible places by scientists or the military
- Currently used by the Navy to power sensors that take readings in remote regions in the oceans
- MFCs can theoretically run for decades without maintenance

Testing the MudWatt







Time (10 second increments)	Normal soil (volts)	Sterilized soil (volts)
1	1.5	0.5
10	1.5	0.5
20	1.5	0.5
30	1.5	0.5
40	1.5	0.5
50	1.5	0.5
60	1.5	0.5
70	1.5	0.5
80	1.5	0.5
90	1.5	0.5
100	1.5	0.5
110	1.5	0.5
120	1.5	0.5
130	1.5	0.5
140	1.5	0.5
150	1.5	0.5
160	1.5	0.5
170	1.5	0.5
180	1.5	0.5
190	1.5	0.5
200	1.5	0.5
210	1.5	0.5
220	1.5	0.5
230	1.5	0.5
240	1.5	0.5
250	1.5	0.5
260	1.5	0.5
270	1.5	0.5
280	1.5	0.5
290	1.5	0.5
300	1.5	0.5

Experiment Ideas

1. Dry vs. wet soil
2. Warm vs. cold environment
3. Soil source
4. Alter soil pH
5. Mix in salt
6. Varying the distance between anode and cathode
7. Supplement the soil with organic matter
 - sucrose solution, winery waste, compost tea, NPK fertilizer, MudWatt mixture (yeast extract, corn syrup, salt, water)
8. Connect MudWatts in series and parallel and investigate energy output

Using the MudWatt in the Classroom

- <http://www.mudwatt.com/pages/educational-resources>

